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Havlena

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(54) SYSTEM AND METHOD FOR PREDICTING FUTURE DISTURBANCES IN MODEL PREDICTIVE CONTROL APPLICATIONS

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC G05B 13/048; G05B 13/042; G05B 13/04; G05B 17/02; G06F 17/5018; G06F 17/5009
USPC 700/29–31; 703/7, 18, 20–21
See application file for complete search history.

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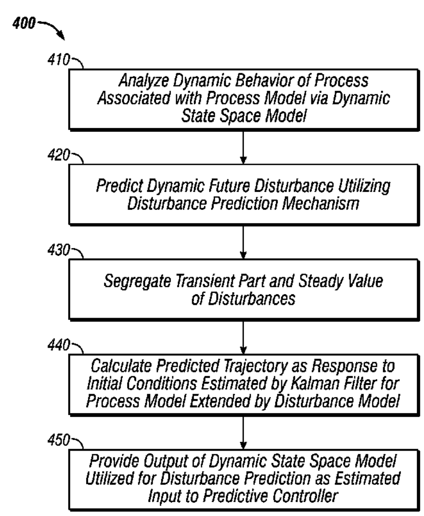
(57) **ABSTRACT**

A system and method for predicting future disturbance in MPC applications by segregating a transient part and a steady state value associated with the disturbance. A dynamic state space model that includes a variable disturbance prediction module can be utilized for analyzing a dynamic behavior of a physical process associated with a process model. The process model represents a dynamic behavior of the physical process being controlled and the dynamic state space model represents current deviations from the process model and future deviations over a predetermined prediction horizon. A predicted trajectory can be calculated as a response to the initial conditions estimated by a Kalman Filter for the process model extended by a disturbance model. The output of the dynamic state space model utilized for the disturbance prediction can be further provided as an estimated input to a MPC.

20 Claims, 5 Drawing Sheets



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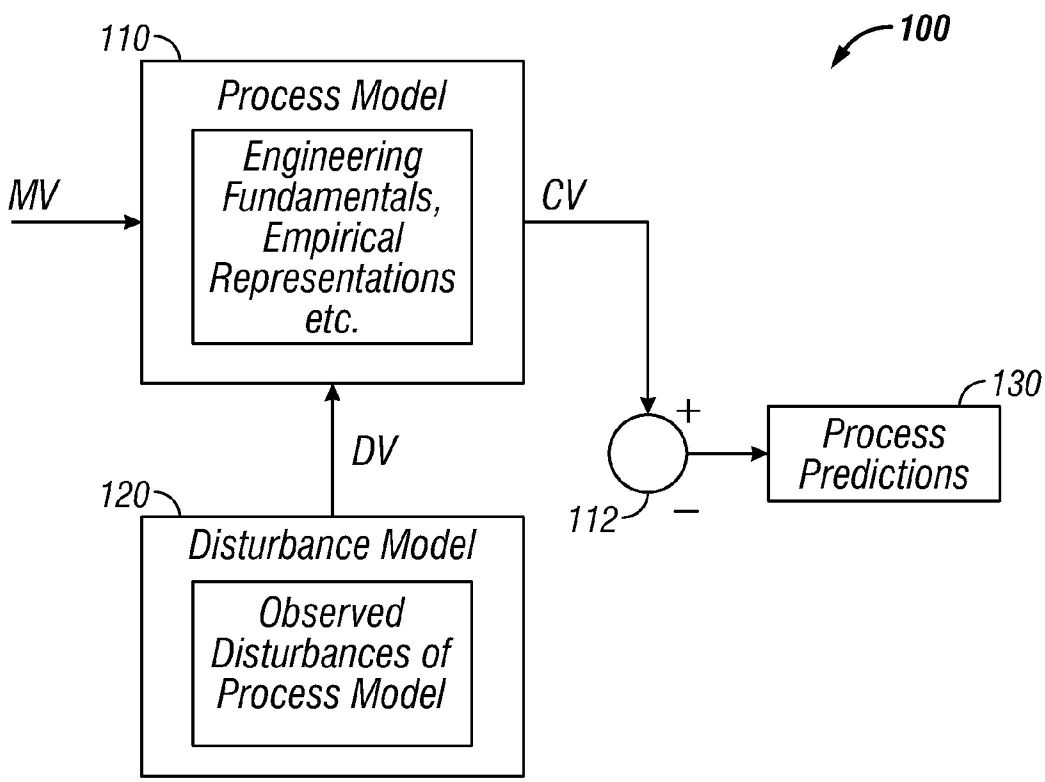

100
110
Process Model
Engineering Fundamentals, Empirical Representations etc.
MV
CV
+
130
Process Predictions
DV
112
−
120
Disturbance Model
Observed Disturbances of Process Model

FIG. 1

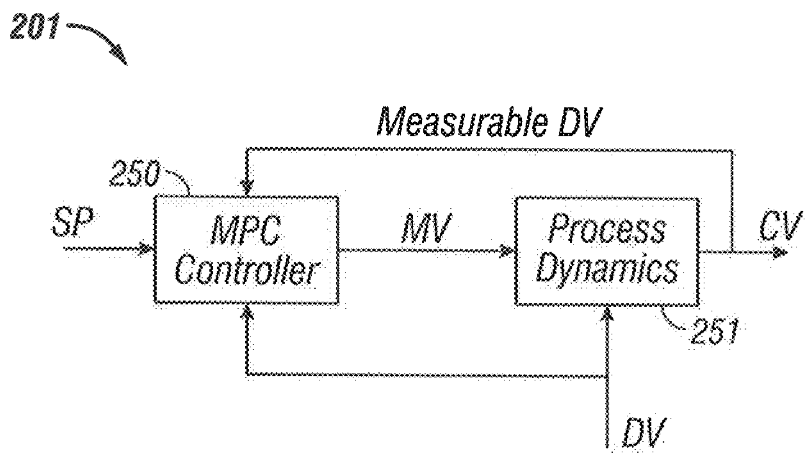

201
Measurable DV
250
SP
MPC Controller
MV
Process Dynamics
CV
251
DV

FIG. 2A

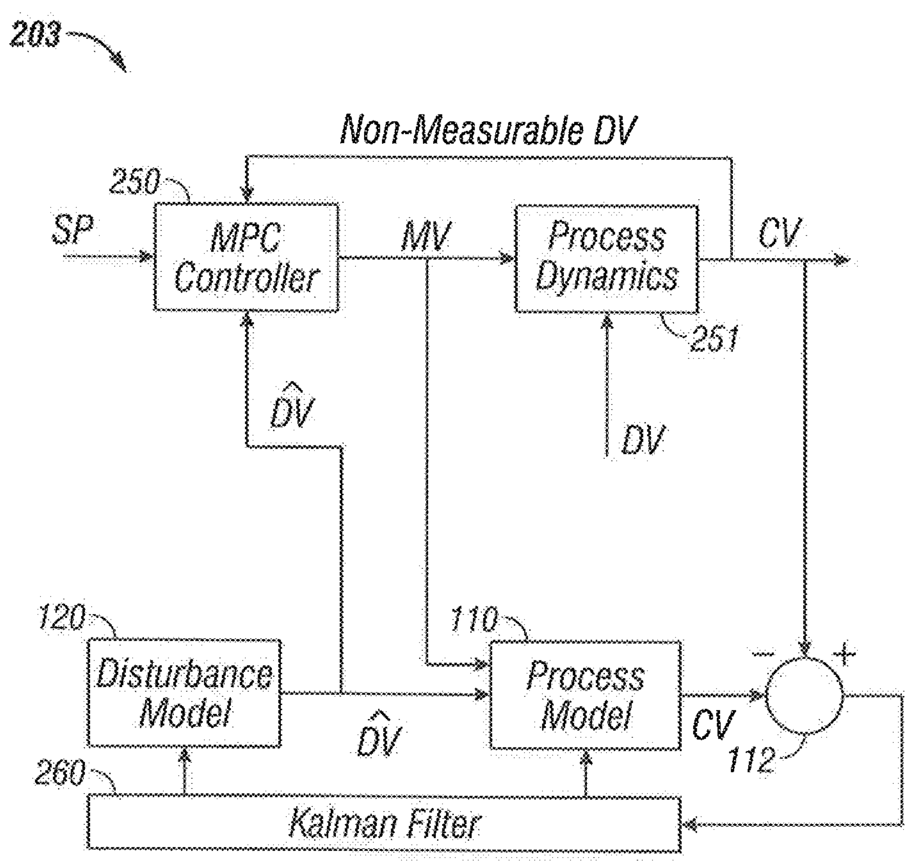
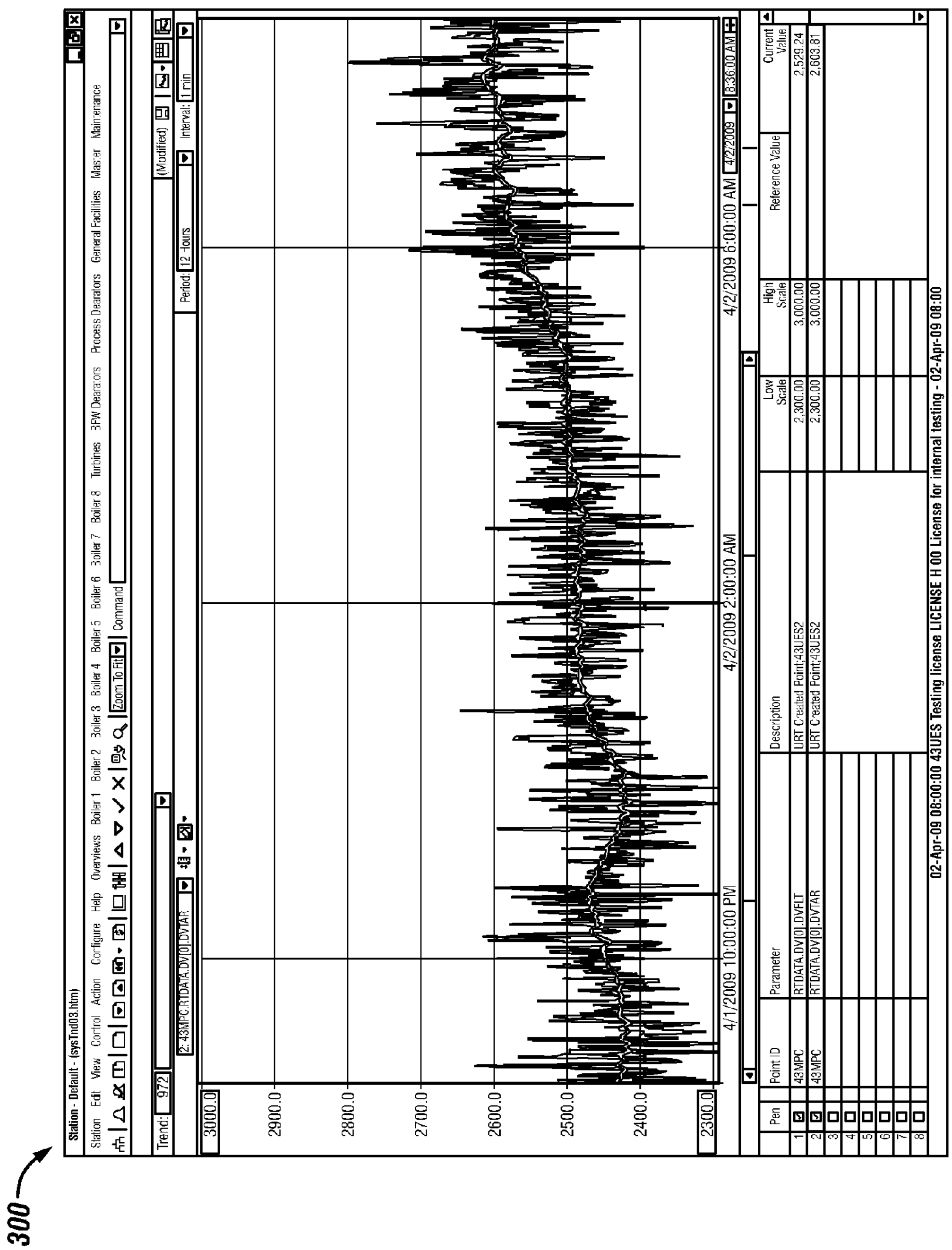

203
Non-Measurable DV
250
SP
MPC Controller
MV
Process Dynamics
CV
251
$\hat{DV}$
DV
120
Disturbance Model
110
Process Model
−
+
CV
112
$\hat{DV}$
260
Kalman Filter

FIG. 2B


300
Station - Default - (sysTrnd03.htm)
Station Edit View Control Action Configure Help Overviews Boiler 1 Boiler 2 Boiler 3 Boiler 4 Boiler 5 Boiler 6 Boiler 7 Boiler 8 Turbines BFW Dearators Process Dearators General Facilities Master Maintenance
Zoom To Fit
Command
Trend: 972
Period: 12 Hours
Interval: 1 min
(Modified)
3000.0
2900.0
2800.0
2700.0
2600.0
2500.0
2400.0
2300.0
4/1/2009 10:00:00 PM
4/2/2009 2:00:00 AM
4/2/2009 6:00:00 AM
8:36:00 AM
Pen
Point ID
Parameter
Description
Low Scale
High Scale
Reference Value
Current Value
43MPC
RTDATA.DV[0].DVFLT
URT Created Point;43UES2
2,300.00
3,000.00
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2,603.81
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FIG. 3

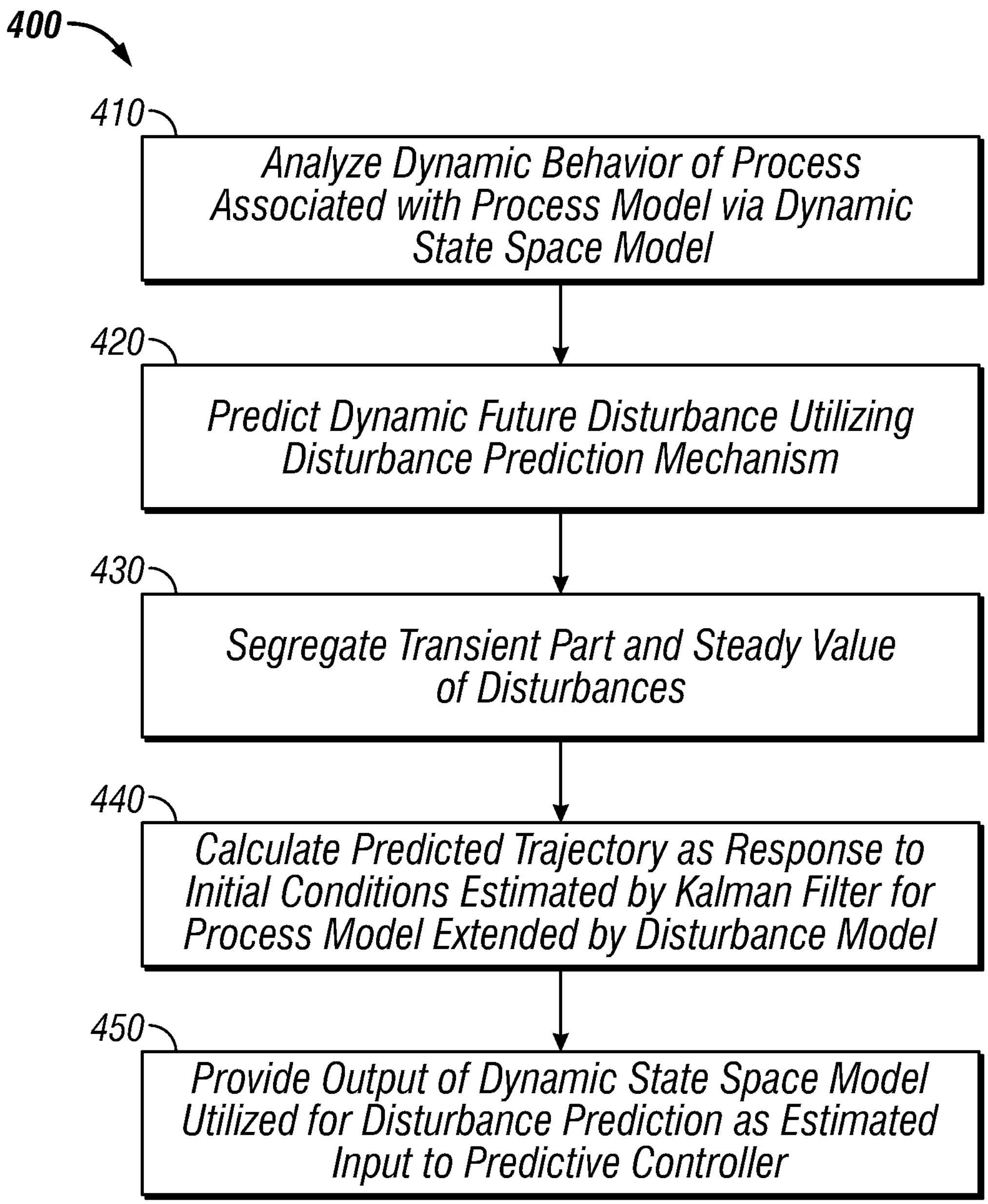
400
410
Analyze Dynamic Behavior of Process Associated with Process Model via Dynamic State Space Model
420
Predict Dynamic Future Disturbance Utilizing Disturbance Prediction Mechanism
430
Segregate Transient Part and Steady Value of Disturbances
440
Calculate Predicted Trajectory as Response to Initial Conditions Estimated by Kalman Filter for Process Model Extended by Disturbance Model
450
Provide Output of Dynamic State Space Model Utilized for Disturbance Prediction as Estimated Input to Predictive Controller

FIG. 4

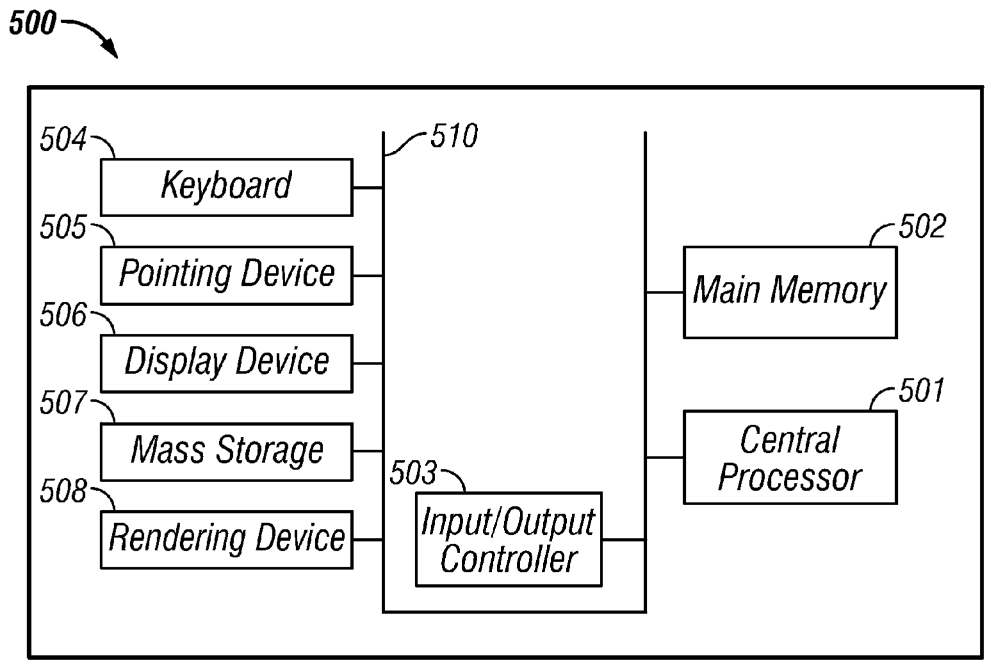
500
504
Keyboard
505
Pointing Device
506
Display Device
507
Mass Storage
508
Rendering Device
510
503
Input/Output Controller
502
Main Memory
501
Central Processor

FIG. 5

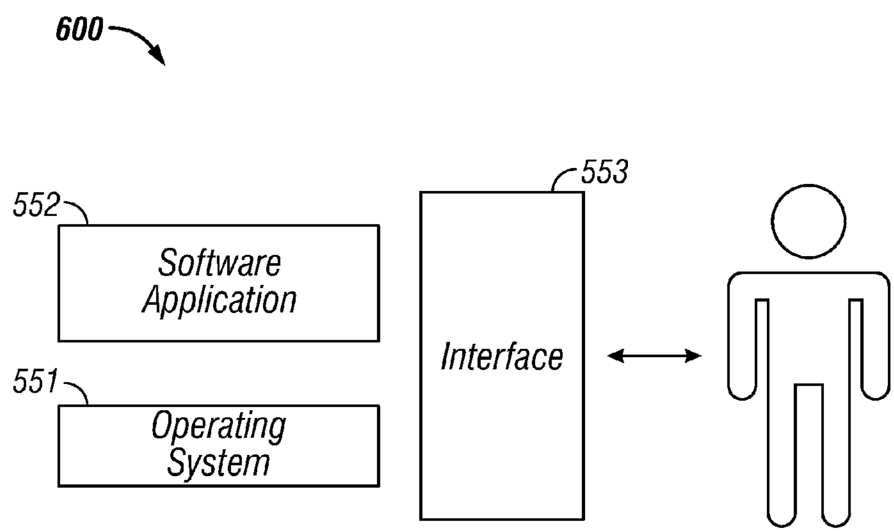
600
552
Software Application
551
Operating System
553
Interface

FIG. 6

SYSTEM AND METHOD FOR PREDICTING FUTURE DISTURBANCES IN MODEL PREDICTIVE CONTROL APPLICATIONS

TECHNICAL FIELD

Embodiments are generally related to process control systems and methods. Embodiments are also related to MPC (Model-based Predictive Control) processes. Embodiments are additionally related to disturbance modeling techniques for model predictive control applications.

BACKGROUND OF THE INVENTION

Process control systems can be utilized to control process facilities such as, for example, chemical, petroleum and other industrial operations. A typical process control system includes one or more process controllers communicatively coupled to each other, to at least one host or operator workstation, and to one or more field devices via analog, digital or combined analog/digital buses. Process facility management providers develop such process control systems to satisfy a wide range of process requirements and facility types. A primary objective of such providers is to control, in a centralized or decentralized system, as many processes as possible to improve the overall efficiency of the facility. Each process, or group of associated processes, possesses certain input (e.g., flow, feed, power, etc) and output (e.g., temperature, pressure, etc) characteristics.

A common approach to advanced industrial process control involves the use of MPC (Model-based Predictive Control) techniques. MPC is a control strategy that utilizes an optimizer to solve for a control trajectory over a future time horizon based on a dynamic model of the process. In the majority of prior art MPC approaches, the current measured disturbance remains constant over the entire prediction horizon because there is no process information in the future. Such a feature may be referred to as a constant additive disturbance assumption. In many, if not most, applications, this adversely affects the regulatory performance of a standard MPC controller. Also, for high-frequency/pulse disturbances, such an approach results in an oscillatory behavior of unforced predictions and significant control effort.

Based on the foregoing, it is believed that a need exists for an improved method and system for predicting future disturbances in an MPC application. Such an improved method and system is described in greater detail herein.

BRIEF SUMMARY

The following summary is provided to facilitate an understanding of some of the innovative features unique to the present invention and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

It is, therefore, one aspect of the present invention to provide for an improved model-based predictive controller, which is capable of predicting future disturbance trajectory

It is another aspect of the present invention to provide for an improved disturbance modeling method and system for MPC applications.

The aforementioned aspects and other objectives and advantages can now be achieved as described herein. A system and method for predicting future disturbance in MPC applications by segregating a transient part and a steady state

value associated with the disturbance is disclosed. A dynamic state space model that includes a variable disturbance prediction module can be utilized for analyzing the dynamic behavior of a physical process associated with a process model. The process model represents the dynamic behavior of the physical process being controlled and the dynamic state space model represents current deviations from the process model and future deviations over a predetermined prediction horizon. A predicted trajectory can be calculated as a response to the initial conditions estimated by a Kalman filter for the process model extended by a disturbance model. The output of the dynamic state space model utilized for the disturbance prediction can be provided as an estimated input to an MPC.

The MPC utilizes the process model and the disturbance model to achieve the desired behavior of the process model by determining process predictions and ultimately provides an optimized output to the process model with a controlled set of parameters. The MPC receives input signals indicative of measured process parameters and the disturbance prediction module perform independent process control decisions which determine manipulated parameter values in response to the input signals. The output from the MPC can be further utilized as a controlled input for the process model to obtain an optimized output. The unforced response can be significantly calmer than prior art techniques; therefore, the proposed approach can be effectively utilized in high frequencies and pulse disturbances. The MPC technique associated with the dynamic future disturbance prediction module is expected to gain widespread acceptance in various industrial process application due to its ability to achieve multivariable control objectives in the presence of dead time, process constraints, and modeling uncertainties.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying figures, in which like reference numerals refer to identical or functionally-similar elements throughout the separate views and which are incorporated in and form a part of the specification, further illustrate the present invention and, together with the detailed description of the invention, serve to explain the principles of the present invention.

FIG. **1** illustrates a block diagram of a process model and a disturbance model employed in a MPC application to determine process predictions, in accordance with an embodiment;

FIGS. **2**A and **2**B illustrate respective block diagrams of process control systems, in accordance with the disclosed embodiment;

FIG. **3** illustrates a trend of an estimated disturbance with separated current and steady state value of the disturbance, in accordance with an embodiment;

FIG. **4** illustrates flow chart of operations illustrating logical operational steps of a method for predicting future disturbance in MPC applications, in accordance with an embodiment;

FIG. **5** illustrates a data-processing apparatus, which may be utilized to carry out an embodiment; and

FIG. **6** illustrates a schematic view of a system that includes an operating system, application software, and a user interface that may be utilized for carrying out an embodiment.

DETAILED DESCRIPTION

The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

FIG. **1** illustrates a block diagram **100** of a process model **110** and a disturbance model **120** employed in the context of an MPC Controller **250** (Model-based Predictive Controller) to determine process predictions **130**, in accordance with an embodiment. Note that in FIGS. **1-4**, identical or similar parts or elements are generally indicated by identical reference numerals. The process model **110** may model, for example, a manufacturing plant, a mineral refinery, or a crude oil refinery that possesses certain input (e.g., flow, feed, power, etc.) and particular output characteristics such as temperature, pressure, etc. The MPC Controller **250** can optimize such characteristics through feedback and actuation. The MPC Controller **250** generally evaluates the observed information and applies an appropriate control strategy to the process model **110** to achieve a desired behavior while rejecting disturbances acting on the process model **110**. The MPC Controller **250** utilizes the process model **110** and the disturbance model **120** to achieve the desired behavior of the process model **110** by determining process predictions **130**.

The process model **110** comprises data associated with the process such as engineering fundamentals, empirical representations, and the like ultimately transformed to a state-space model. The disturbance model **120** may constitute, for example, the dynamic response of observed disturbances ultimately transformed to a state-space model with respect to each disturbance input to the process. Data from the disturbance model **120** is input as DV (Disturbance Variables) to the process model **110**. Note that the DV is just an additional input to the process and can enter the process model **110** at any point and is not limited to additive disturbances on process input.

MV (Manipulated Values or Variables) can be additionally input to the process model **110**. The MPC Controller **250** integrates data from the process model **110** and the disturbance model **120** for determining manipulated value MV (process input) trajectory **130**. The MV trajectory **130** can thus be utilized as a controlled input for the process model **110** to obtain an output prediction. The process model **110** represents a dynamic behavior of the physical process being controlled and the disturbance model **120** represents estimated disturbance based on current deviations of measured process output from the process model output **110** and future trajectory of the disturbance over a predetermined prediction horizon. Note that the process model and the disturbance model described herein are mathematical models for calculating the process and disturbance predictions.

FIGS. **2A-2B** illustrates respective block diagrams of a process control system **201** and a process control system **203**, in accordance with the disclosed embodiments. Note that in FIGS. **2A-2B**, identical or similar parts or elements are generally indicated by identical reference numerals. As indicated in FIG. **2A**, the process control system **201** generally includes an MPC controller **250** whose output is fed as input to a process dynamics module **251**. In the configuration depicted in FIG. **2A** of system **201**, a single MPC controller **250** is depicted. In the configuration of system **203** depicted in FIG. **2B**, the MPC controller **250** communicates with the process dynamics module **251** and receives input from the disturbance model module **120**, which in turn provides input to process model module **110**. A Kalman filter **260** shown in FIG. **2B** provides input data to the disturbance model **120** and the process model **110**. The Kalman filter **260** generally constitutes a process for estimating the value of parameters in the presence of, for example, noise and time delays. Note that while the controller **250** can calculate the optimal input based on the estimated DVAˆhat, the real process dynamics of module **251** can respond to the real (i.e., but unmeasurable) disturbance DV.

FIGS. **2A-2B** generally illustrates the fact that while for measurable disturbances, the value of DV can be used for feed forward DV compensation (under the assumption that future DV values will be equal to its current value—FIG. **2A**), but for unmeasurable DVs, the current value has to be estimated (estimated values are indicated with a hat ˆ). However, the use of estimated value provides another degree of freedom-based on the dynamic model of the DV used for the estimation of its current value and the current initial state of the "disturbance generator", also its future trajectory can be calculated and used as the FF in MPC algorithm (FIG. **2B**).

The process control system **201** and/or **203** may be configured as part of a distributed or scalable control process utilized in, for example, chemical, petroleum, and other industrial processes such as manufacturing plants, mineral, or crude oil refineries, etc. Note that the disclosed approach, although discussed in the context of a single MPC controller **250**, may be employed in much more complex processes wherein multiple MPC controllers are utilized. The process control system **201** and/or **203** can be adapted for controlling a process utilizing optimal multivariable controllers in particular model predictive control (MPC) techniques. The MPC Controller **250** can be programmed utilizing any number of optimization techniques such as, for example (but not limited to) standard Quadratic Programming (QP) and/or Linear Programming (LP) techniques to predict values for the control outputs. The MPC Controller **250** can be implemented in the form of online optimization and/or by using equivalent lookup tables computed with a hybrid multi-parametric algorithm depending on the complexity of the problem.

The MPC controller **250** shown in FIG. **2A** may communicate with both the process model **110** and the independent disturbance model **120**. The disturbance model **120** can be a dynamic state space model utilized for disturbance prediction. The process model **110** can be characterized by controlled variables (CV) or process output variables and disturbance variables DV. As indicated in FIG. **2B**, the DV are input to the process model **110** along with manipulated variables (MV) output from the MPC controller **250**. CV are output from the process model **110** and supplied as input to the summation device **112**. Note that the MV constitutes process input variables to both the process model **110** and the process dynamics module **251**. CV are also output from process dynamics module **251** and fed as input to the summation device **112**. Such a system or process can be applied to any form of operation in which the effects of changes in the MV and DV generate some changes in the CV over a period of time.

A steady state represents final state of the process following the changes in the MV and/or the DV. For a stable process, the steady state is achieved when the rate of change of its output variables becomes zero for inherently stable process or the rate of change of its output attains a constant value. For open-loop unstable process, such as liquid accumulator, the steady state can be achieved when the rate of change of its output variables attain a constant value. The process model **110** characterized in FIGS. **2A** and/or **2B** can be a simple process involving one input variable and one output variable or a more complex process involving multiple input variables and multiple output variables.

A predicted DV trajectory may be calculated as a response to the initial conditions estimated by the Kalman Filter **260** for the process model **110** extended by the disturbance model **120**. The Kalman Filter **260** may be provided in the context of an optimal filtering technique utilized for estimating the state variables of the process model **110**. The Kalman Filter **260** can be a time domain operation that is suitable for use in estimating the state variables of linear time-varying systems that can be described by a set of, for example, discrete models. The Kalman Filter **260** can be generally utilized for state estimation in many process models **110** that may be approximately described as linear. The output of the disturbance model **120** utilized for the disturbance prediction can be further provided as an estimated input to the MPC controller **250**.

The MPC Controller **250** can determine the behavior of the process model **110** for the obtained disturbances and ultimately provides an optimized output to the process model **110** with a controlled set of parameters. The MPC Controller **250** can utilize both linear and non-linear optimization to determine the manipulations of processes within the process model **110** that is required to achieve the desired set of controlled parameters. The output signals transmitted from the MPC controller **250** include one or more manipulated parameter values that govern the process model **110**.

FIG. **3** illustrates a GUI **300** of a pulse disturbance model, in accordance with an embodiment. The GUI **300** represents a predicted trajectory, which may be a pulse signal model for disturbance signal from the disturbance model **120**. As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components.

FIG. **4** illustrates a flow chart of operations illustrating logical operational steps of a method **400** for predicting future disturbance in MPC applications, in accordance with an embodiment. The dynamic behavior of a physical process associated with the process model **110** can be analyzed via the dynamic state space model **120** in order to manipulate functions representing future disturbances, as depicted at block **410**. The future disturbances can be predicted utilizing the disturbance prediction module associated with the dynamic state space model, as illustrated at block **420**. The transient part and the steady state value of the disturbances can be segregated, as depicted at block **430**. Further, the predicted trajectory can be calculated as a response to the initial conditions estimated by the Kalman filter **260** for the process model **110** extended by the disturbance model **120**, as shown at block **440**. The output of the dynamic state space model utilized for the disturbance prediction can be provided as estimated input to the MPC Controller **250**, as illustrated at block **450**.

The MPC Controller **250** utilizes the process model **110** and the disturbance model **120** to achieve the desired behavior of the process model **110** by determining process predictions and ultimately provides an optimized output to the process model **110** with a controlled set of parameters. The output from the MPC Controller **250** can be further utilized as a controlled input for the process model **110** to obtain an optimized output. The unforced response can be significantly calmer; therefore, the proposed approach can be effectively utilized in high frequencies and pulse disturbances. The MPC technique associated with the dynamic future disturbance prediction module can gain a widespread acceptance in the process model due to its ability to achieve multi-variable control objectives in the presence of dead time, process constraints, and modeling uncertainties.

FIGS. **5-6** are provided as exemplary diagrams of data processing environments in which embodiments of the present invention may be implemented. It should be appreciated that FIGS. **5-6** are only exemplary and are not intended to assert or imply any limitation with regard to the environments in which aspects or embodiments of the present invention may be implemented. Many modifications to the depicted environments may be made without departing from the spirit and scope of the present invention. FIGS. **5-6** are provided to demonstrate that the methodology described herein can be implemented in the context of software and various software applications, including software modules and the like. Note that the various features and aspects shown herein may be provided as such modules. For example, the process model **110**, the disturbance model **120**, and the process predictions component **130** disclosed in FIG. **1** may be, for example, software modules. Similarly, the Kalman Filter **260**, process dynamics **251**, the MPC controller **250**, and so forth may also be implemented in the context of software modules. Systems **201** and **203**, for example, may also be implemented in the context of software modules and/or software applications (e.g., software application **552** shown in FIG. **5**).

FIG. **5** illustrates an example of a data-processing apparatus **500**, which may assist in carrying out an embodiment. The data-processing apparatus **500** generally includes a central processor **501**, a main memory **502**, an input/output controller **503**, an input device such as, for example, a keyboard **504**, a pointing device **505** (e.g., mouse, track ball, pen device, or the like), a display device **506**, and a mass storage **507** (e.g., hard disk). Additional input/output devices, such as a rendering device **508**, may be utilized in association with the data-processing apparatus **500** as desired. As illustrated, the various components of the data-processing apparatus **500** communicates through a system bus **510** or similar architecture.

FIG. **6** illustrates an example of a software system **600** that can be utilized for directing the operation of the data-processing apparatus **500**. Software system **550**, which is stored in system memory **502** and on disk memory **507**, includes a kernel or operating system **551** and a shell or interface **553**. One or more application programs, such as application software **552**, may be "loaded" (i.e., transferred from storage **507** into memory **502**) for execution via the data-processing apparatus **500**. The data-processing apparatus **500** receives user commands and data through user interface **553**; these inputs may then be acted upon by the data-processing apparatus **500** in accordance with instructions from operating module **551** and/or application module **552**.

The interface **553**, which is preferably a graphical user interface (GUI), also serves to display results, whereupon the user may supply additional inputs or terminate the session. In one particular embodiment, operating system **551** and interface **553** can be implemented in the context of a "Windows" system. Thus, interface **553** may be, for example, a GUI such as GUI **300** described earlier. In another embodiment, operating system **551** and interface **553** may be implemented in the context of other operating systems such as Linux, UNIX, etc. Application module **552**, on the other hand, can include instructions such as the various operations described herein with respect to the various components and modules described herein. Such instructions may process, for example, the method **400** described herein with respect to FIG. **4**.

It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also, that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. A method for predicting disturbances of a physical process, said method comprising:

analyzing the dynamic behavior of a physical process of a mineral refinery associated with a process model via a dynamic state space model thereby manipulating functions representing future disturbances;

predicting said future disturbances utilizing a disturbance prediction module associated with said dynamic state space model;

segregating a transient part and segregating a steady state value of said-disturbances associated with said process model, indicative of said dynamic behavior of said physical process associated with said mineral refinery being controlled thereto;

calculating a predicted trajectory as a response to an initial condition estimated by a Kalman Filter based on outputs of said process model and said disturbance model;

estimating a future deviation using said disturbance prediction module; generating an estimated disturbance prediction output of said disturbance model based on the predicted trajectory;

inputting said estimated disturbance prediction output into a separate external model-based predictive controller wherein said model based predictive is implemented as an online optimization and uses equivalent lookup tables computed according to a hybrid multi-parametric algorithm;

providing manipulated variables from said model-based predictive controller to a process dynamics module; wherein said manipulated variables are determined based on said estimated disturbance prediction output; wherein said output of said process dynamic module is determined based on an actual disturbance variable and said manipulated variable; wherein said output of said process model is determined based on said estimated disturbance prediction output and said manipulated variables;

determining process predictions by said model-based predictive controller based on said disturbance prediction output and thereafter providing an optimized output as a controlled input to said process model; and

controlling said physical process based on said optimized output as a controlled input.

2. The method of claim **1** further comprising:

inputting disturbance variables from said disturbance model into said process model wherein said disturbance model comprises a dynamic response of observed disturbances transformed to a dynamic state space model.

3. The method of claim **2** further comprising:

estimating said future deviation as a function of a past deviation and a current deviation from said process model by said disturbance prediction module; and

inputting said disturbance variables into said model predictive controller.

4. The method of claim **3** wherein said disturbance model provides data indicative of said current deviation from said process model and said future deviation over a predetermined prediction horizon.

5. The method of claim **4** further comprising transmitting an input signal indicative of a measured process parameter to said model-based predictive controller.

6. The method of claim **5** wherein said disturbance prediction module performs an independent process control decision to determine manipulated parameter values in response to said input signal.

7. The method of claim **6** further comprising transmitting a command signal from said model-based predictive controller to said process model external to said model-based predictive controller which include said manipulated parameter value to govern said process model.

8. A system for predicting disturbances, said system comprising:

a processor;

a data bus coupled to said processor; and

a computer-usable medium embodying computer code, said computer-usable medium being coupled to said data bus, said computer program code comprising instructions executable by said processor and configured for:

analyzing the dynamic behavior of a physical process of a mineral refinery associated with a process model via a dynamic state space model thereby manipulating functions representing future disturbances;

predicting said future disturbances utilizing a disturbance prediction module associated with said dynamic state space model;

segregating a transient part and segregating a steady state value of said disturbances associated with said process model, indicative of said dynamic behavior of said physical process associated with said mineral refinery being controlled thereto;

calculating a predicted trajectory as a response to an initial condition estimated by a Kalman Filter based on outputs of said process model and said disturbance model;

estimating a future deviation using sad disturbance prediction module;

generating an estimated disturbance prediction output of said disturbance model based on the predicted trajectory;

inputting said estimated disturbance prediction output into a separate external model predictive controller wherein said model based predictive controller implemented as an online optimization and using equivalent lookup tables computed according to a hybrid multi-parametric algorithm;

providing manipulated variables from said model-based predictive controller to a process dynamics module; wherein said manipulated variables are determined based on said estimated disturbance prediction output; wherein said output of said process dynamic module is determined based on an actual disturbance variable and said manipulated variable; wherein said output of said process model is determined based on said estimated disturbance prediction output and said manipulated variables;

determining process predictions by said model-based predictive controller based on said disturbance prediction output and thereafter providing an optimized output as a controlled input to said process model, and controlling said physical process based on said optimized output as a controlled input.

9. The system of claim 8 further comprising:

inputting disturbance variables from said disturbance model into said process model wherein said disturbance model comprises a dynamic response of observed disturbances transformed to a dynamic state space model.

10. The system of claim 9 wherein said instructions are further configured for:

estimating said future deviation as a function of a past deviation and a current deviation from said process model by said disturbance prediction module; and

inputting said disturbance variables into said model predictive controller.

11. The system of claim 10 wherein said instructions are further configured for generating from said disturbance model, data indicative of said current deviation from said process model and said future deviation over a predetermined prediction horizon.

12. The system of claim 11 wherein said instructions are further configured for transmitting an input signal indicative of a measured process parameter to said model predictive controller.

13. The system of claim 12 wherein said instructions are further configured for performing via said disturbance prediction module, an independent process control decision to determine manipulated parameter values in response to said input signal.

14. The system of claim 13 wherein said instructions are further configured for transmitting a command signal from said model predictive controller to said process model external to said model-based predictive controller which includes said manipulated parameter value to govern said process model.

15. A non-transitory computer-readable medium for authorizing access to a secure location, said computer-readable medium embodying a computer program code, said computer program code comprising computer executable instructions configured for;

analyzing the dynamic behavior of a physical process of a mineral refinery associated with a process model via a dynamic state space model thereby manipulating functions representing future disturbances;

predicting said future disturbances utilizing a disturbance prediction module associated with said dynamic state space model;

segregating a transient part and segregating a steady state value of said-disturbances associated with said process model, indicative of said dynamic behavior of said physical process associated with said mineral refinery being controlled thereto;

calculating a predicted trajectory as a response to an initial condition estimated by a Kalman Filter based on outputs of said process model and said disturbance model;

estimating a future deviation using said disturbance prediction module; generating an estimated disturbance prediction output of said disturbance model based on the predicted trajectory;

inputting said estimated disturbance prediction output into a separate external model predictive controller wherein said model predictive controller is implemented as an online optimization and uses equivalent lookup tables computed according to a hybrid multi-parametric algorithm;

providing manipulated variables from said model-based predictive controller to a process dynamics module; wherein said manipulated variables are determined based on said estimated disturbance prediction output; wherein said output of said process dynamic module is determined based on an actual disturbance variable and said manipulated variable; wherein said output of said process model is determined based on said estimated disturbance prediction output and said manipulated variables;

determining process predictions by said model-based predictive controller based on said disturbance prediction output and thereafter providing an optimized output as a controlled input to said process model; and

controlling said physical process based on said optimized output as a controlled input.

16. The non-transitory computer-readable medium of claim 15 further comprising:

inputting disturbance, variables from said disturbance model into said process mode wherein said disturbance model: comprises a dynamic response of observed disturbances transformed to a dynamic state space model.

17. The computer-usable medium of claim 16 wherein said embodied computer program code further comprises computer executable instructions configured for estimating said future deviation as a function of a past deviation and a current deviation from said process model by said disturbance prediction module; and

inputting said disturbance variables into said model predictive controller.

18. The non-transitory computer-readable medium of claim 17 wherein said embodied computer program code further comprises computer executable instructions configured for generating via said disturbance model, data indicative of said current deviation from said process model and said future deviation over a predetermined prediction horizon.

19. The non-transitory computer-readable medium of claim 18 wherein said embodied computer program code further comprises computer executable instructions configured for performing via said disturbance prediction module, an independent process control decision to determine manipulated parameter values in response to said input signal.

20. The non-transitory computer-readable medium of claim 19 wherein said embodied computer program code further comprises computer executable instructions configured for:

transmitting an input signal indicative of a measured process parameter to said model predictive controller; and

transmitting a command signal from said model predictive controller to said process model external to said model-based predictive controller which includes said manipulated parameter value to govern said process model.

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